PARAMETER IDENTIFICATION OF A COUPLED TANK LIQUID LEVEL SYSTEM VIA PARTICLE SWARM OPTIMIZATION

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SUPERVISOR'S DECLARATION

"I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor of Electrical Engineering (Control & Instrumentation)"

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ABSTRACT

This project focuses on obtaining a mathematical equation for a coupled tank liquid level system. The aim of this project is to identify and obtain the mathematical modeling utilizing Particle Swarm Optimization (PSO). The level of water in each tank is monitored by a capacitive-type probe. Signal conditioning circuits convert the measured capacitance (a function of the water level) to electrical signals in the range 0 to +5 Volt DC. Output from simulated and modeling performance are compared until *n* set number of iteration for error less output. The fitness function which equal to the sum of errors less square over number of iteration is later used in Visual Basic. Using Visual Basic, a GUI is developed to analyze and display both performances in terms of graph. In addition, both performances are also analyzed in terms of its transient and steady-state responses. The obtained mathematical equation can further be used for controller development such as by simulation in MATLAB/Simulink

ABSTRAK

Projek ini tertumpu pada mendapatkan persamaan matematik untuk tahap cair tangki ditambah sistem. Objektif dari projek ini adalah untuk mengenalpasti dan mendapatkan model matematik memanfaatkan Particle Swarm Optimization (PSO). Paras air di masing-masing tangki dipantau oleh probe taip kapasitif. Litar pengkondisian isyarat menukar Kapasitans terukur (fungsi dari peringkat air) kepada isyarat-isyarat elektrik pada kisaran 0-5 Volt DC. Output daripada simulasi dan pemodelan prestasi berbanding sampai n jumlah iterasi menetapkan untuk kesalahan kurang output. Kebugaran fungsi yang sama dengan jumlah kuadrat kesalahan kurang lebih jumlah iterasi yang kemudian digunakan dalam Visual Basic. Menggunakan Visual Basic, GUI yang dibangunkan untuk menganalisis dan memaparkan persembahan, baik dalam hal grafik. Selain itu, kedua persembahan juga dianalisis dari segi transien dan tanggapan keadaan tunak. Persamaan matematik yang diperolehi selanjutnya dapat digunakan untuk pengembangan controller seperti dengan simulasi di MATLAB / Simulink

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LIST OF ABBREVIATIONS

PLC	Programmable Logic Control
SISO	Single Input Single Output
MIMO	Multi Input Multi Output
Analog I/O	Analog Input Output
DM	Data Memory
CPU	Computer Processing Unit
PSO	Particle Swarm Optimization
GUI	Graphical User Interface
MSE	Mean Square Error
MV	Manipulated Variable
CV	Controlled Variable
SP	Set Point

CHAPTER 1

INTRODUCTION

1.1 Introduction

1.1.1 Coupled Tank Liquid Level System

The coupled tank apparatus CTS-001 is a computer-controlled coupled-tank system used for liquid level control. The concept of virtual instrumentation is introduced in CTS-001. By using virtual instrumentation techniques, the need for traditional dedicated user interfaces on individual instruments can be eliminated [1]. Instead, the computer can be used to provide the interface normally required on each of the individual instruments, reducing cost and complexity. Virtual instrumentation also allows the user to make major modification to the instrument by simply changing a software program. For example, the computer can be used to carry out the functions of an oscilloscope for displaying input and output response.

1.1.2 Parameter Identification

A Parameter Identification or in the other word as model is a set of mathematical equations that are intended to capture the effect of certain system variables on a certain other system variables. It is usually neither possible nor necessary to model the effect of every variable on every other variable; one therefore limits oneself to certain subsets, for example, the effect of disturbance on output [2]. A model is never perfect and it is therefore always associated with a modeling error. The importance of this mathematical model implemented for the Coupled Tank Water Level systems are it is frequently observed in practice in control plant in today's larger industries and it can be easily use in future when doing MATLAB simulation.

The most traditional system identification techniques are prediction error method (PEM) and the instrument variable method (IVM). Though these traditional identification techniques offer good solution to many real-life systems, they have certain issues like difficulty in determining the model structure and numerical reliability due to need of solving the multidimensional nonlinear optimization problem in PEM case or system of linear equations in IVM case [3]. In another research, it introduced Transfer Function Matrix which is based on the transfer function approach, for example, direct polynomial form of TF and direct frequency domain identification.

1.1.3 Particle Swarm Optimization

The Particle Swarm Optimization (PSO) algorithms are populated-based research algorithm based on the simulation of the social behavior of birds within a flock [4]. They work in the same way, which is, updating the population of individuals by applying some kind of operators according to the fitness information obtain from the environment so that the individuals of the population can be expected to move toward better solution areas [5]. PSO is one from other Intelligent Method of Parameter Identification that is

famously used in today control process because it has stochastic search capability and robustness [6].

Thus, in this paper, it proposes the use of Particle Swarm Optimization in identifying a fitness function for the mathematical equation. The objectives of this project are to identify and obtain the mathematical characteristic of the Coupled Tank Liquid Level system using a suitable parameter identification technique which is the Intelligent Method. Secondly is to develop GUI which will display the actual system performance (in terms of graphs) along with the model performance. In addition to that, both performances will also be analyzed in terms of transient and steady-state responses.

1.2 Problem Statement

There are three major statements that have been emphasized in this project which are Coupled Tank Water Level System, Programmable Logic Controller and Parameter Identification.

1.2.1 Coupled Tank Liquid Level System

Coupled Tank is very special and unique due to the coupled function. There are two major applications in Coupled Tank which is SISO (Single Input Single Output) and MIMO (Multiple Input Multiple Output). The level of water entering tank 1 will be affected by the water level in tank 2. In industrial control application, it is often required to control Coupled Tank Water Level System. It is very popular and widely used in control process industries.

1.2.2 Programmable Logic Controller

Programmable Logic Controller can be thought of as Industrial Computers with specially designed architecture in both their central units (the PLC itself) and their interfacing circuitry to field devices (input /output connections to the real world). PLC is able to received analog external input and produced analog output for its functionality.

1.2.3 Parameter Identification

In Parameter Identification, Particle Swarm Optimization Method is applied because of its free derivation. It required less number of computations to achieve same error goals. PSO varied in real-time, so it is easy to use in software simulation.

1.3 Objective

The overall objectives of this project are;

1. To identify and obtain the Mathematical Model of Coupled Tank Liquid Level System using Particle Swarm Optimization Method in terms of its transfer function.
2. To estimate the parameter coefficient of the transfer function utilizing an intelligent technique namely Particle Swarm Optimization.

1.4 Scope of Project

The scopes of this project are;

1. To determine the modeling mathematical equation of Coupled Tank Water Level System using Particle Swarm Optimization.

2. To compare the modeling output with simulated output to obtain error less between both output.
3. To develop GUI that will display the simulated and model performance in terms of graph
4. To analyze the model performance in terms of transient and steady-state response.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, all the important information related to this project are reviewed. The sources of this information are mains from journals, conference papers, manuals, and website. Besides that, the literature review can give a brief explanation about Parameter Identification and the important of using Particle Swarm Optimization in order to obtain the mathematical equation which best representing the Coupled Tank Liquid Level System.

2.2 Coupled Tank Liquid Level System

The reservoir contains two PWM operated motor pumps. These pumps use either 0-5V analog voltage (internal signal conditioning system convert analog to PWM (digital signal)) or external PWM sources for their application. Flow rates of water into tank can be varied by change of these pump voltages. There is a baffle plate separating

the two tanks which can be slide up and down to vary interaction and coupling capacitive probes, one in each tank, provided to measure water level. Output signals from these probes are conditioned to give 0-5V analog output. A water outlet at side near base of each tank connected by a flexible tube returns water to reservoir [1].

2.2.1 Coupled Tank Liquid Level System Application

The industrial application of liquid level control is tremendous especially in chemical process industries. Usually, level control exists in some of the control loops of process control system. Otherwise in many other industrial applications are concerned with level control, may it be a single loop level control or sometimes multi-loop level control. In some cases, level controls that are available in the industries are for interacting tanks. Hence, level control is one of the control system variables which are very important in Process Industries.

2.3 Parameter Identification

In the design of adaptive control system, it is sometime necessary to estimate parameters for systems represented by state-space response [2]. Some generic and user-friendly tools are available for model identification. For example, System Identification Toolbox of MATLAB that contains various techniques for identifying time-series and state space, non parametric and parametric models, is a popular identification tool among researchers and academicians.

2.3.1 Parameter Identification Application

Once the system (plant) generate the output in terms of graph , the usage of Parameter Estimation problem is to find among all possible choices a particular set of parameters which best describes the system. Depending on one’s definition of “best”

there are different approaches to such a Parameter Identification problem [2]. In this research, Intelligent Method is used instead of Classical Method. In Intelligent Method, Particle Swarm Optimization is selected to be used in this research based on the popularity of this method in process industry.

2.4 Particle Swarm Optimization

PSO algorithm was developed in 1995 by James Kennedy (social-psychologist) and Russell Eberhart (electrical engineer), which is a Robust Stochastic Optimization technique based on the movement and intelligence of swarms. It uses a number of particles that constitute a swarm moving around in the search space looking for the best solution [6].

In PSO algorithm, a swarm consists of m-particle, in which each particle is treated as a point in an N-dimensional space which adjusts its "flying" according to its own flying experience as well as the flying experience of other particles. Each particle uses velocity to determine the direction and value of its "flying", which follow the current optimum in an N-dimension space [6].

Each particle keeps track of its coordinates in the solution space which are associated with the best solution that has achieved so far by that particle. This value is called personal best *Pbest.* Another best value that is tracked by the PSO is the best value obtained so far by any particle in the neighborhood of that particle. This value is called global best, *Gbest* .The basic concept of PSO lies in accelerating each particle toward its personal best and the global best locations.

PSO does not have genetic operators like crossover and mutation. Particles update themselves with the internal velocity. They also have memory, which is

important to the algorithm. In PSO, only Gbest gives out the information to others. It is a one way information sharing mechanism. The evolution only looks for the best solution.

2.5 Programmable Logic Controller

A programmable logic controller (PLC) is an industrial computer used to control and automate complex systems. All CJ1 series use the same instruction set and I/O modules, so existing programs and equipment can be easily reused. A common memory area can help integrate processes or coordinate various activities. Besides, CJ1M also provide the analog output with the current rating from 4mA to 20mA which the CQM1H cannot provide both of them [7].

Programmable logic controllers are a relatively recent development in process control technology. It is designed for use in an industrial environment, which uses a programmable memory for integral storage of user-oriented instructions for implementing specific functions such as logic, sequencing, timing, counting, and arithmetic to control through digital or analog inputs and outputs, various types of machines or processes [8].

2.5.1 PLC Application

Programmable logic controllers are widely used in industry and process control. Programmable logic controllers are used in a wide spectrum of applications from factory automation to waste water treatment plant controls and from chemical process plant control to engine management systems. PLCs are used throughout industry to control and monitor a wide range of machines and other movable components and systems. As a part of process control, a PLC is used to monitor input signals from a variety of input points (input sensors) which report events and conditions occurring in a controlled process. For example, a PLC can monitor such input conditions as motor speed, positioning, temperature, pressure and volumetric flow. Its associated peripherals are

designed so that they can be easily integrated into an industrial control system and easily used in all their functions [9].

2.6 Matlab Simulink

Simulink is an environment for multi-domain simulation and Model-Based Design for dynamic and embedded systems. It provides an interactive graphical environment and a customizable set of block libraries that let you design, simulate, implement, and test a variety of time-varying systems, including communications, controls, signal processing, video processing, and image processing. Simulink provides a graphical user interface for building math models as block diagrams. The graphical interface is popular for developing dynamical models for many fields, such as electronics, hydraulics, chemistry, and especially, control systems.

2.7 Graphical User Interface (GUI)

Microsoft released Visual Basic in 1987 and the latest is in 2008. It was the first visual development tool from Microsoft, and it was to compete with C, C++, Pascal and other well-known programming languages. Programmers have undergone a major change in many years of programming various machines. Overall, it can class Visual Basic as a Graphical User Interface (GUI). A GUI is a graphical (rather than purely textual) user interface to a computer.

Today's major operating systems provide a graphical user interface. Applications typically use the elements of the GUI that come with the operating system and add their own graphical user interface elements and ideas. When creating an application, many object-oriented tools exist that facilitate writing a graphical user interface. Each GUI element is defined as a class widget from which you can create object instances for your application.